Chapter 5
Water Distribution System

Water meter

This chapter focuses on the SPU water distribution system, the part of the Transmission and Distribution business area that involves delivery of water for retail use and for fire flow. SPU's water distribution system consists of water mains, distribution storage facilities and pump stations, and related appurtenances such as valves, hydrants, service connections, and retail billing meters. The supervisory control and data acquisition (SCADA) system used to monitor and control the water system is also discussed in this chapter. Proper management of the distribution system ensures that SPU meets its service levels for retail customers.

5.1 WATER DISTRIBUTION SYSTEM POLICIES

SPU developed the following new policy to describe SPU's decision-making process and criteria for addressing redundancy in the distribution system.

5.1.1 Distribution System Redundancy Policy

Redundancy in the distribution system is one way that SPU can increase the reliability of water delivery to its retail service customers. Distribution system redundancy is provided by the network of water mains, appropriately spaced valves, stand-by pumps, and storage, all of which can help minimize customer outages. Increasing redundancy, however, adds capital and operation and maintenance (O&M) costs that may not necessarily be justified. This policy was developed to incorporate asset management principles, primarily life-cycle benefit and cost analysis, into SPU's decision-making and clearly establish the criteria that SPU will use for adding or retiring redundancy in its water distribution system. This policy ensures that service reliability is considered along with costs when considering retirement of existing redundant facilities or adding new redundancy. In developing this policy, SPU aimed to balance the consequences and costs of failure with the benefits of redundancy. It favors adding redundancy only when it is cost-justified - meaning the benefits outweigh the costs.

Policy Statement

Consider redundancy in the distribution system on a case-by-case basis, with decisions based on an evaluation of net present value.

Net present value (NPV) compares the value of a dollar today to the value of the same dollar at some time in the future by accounting for inflation and interest.

1. *For new developments or redevelopments within the distribution system, require developers to install looped systems, intermediate line valves, and/or additional shut-off valves for dead-end water mains when SPU determines that the improvement provides a positive net present value to the water system in the area.*

2. *Consider retiring existing redundant facilities within the distribution system when they are at the end of their economic life and the costs of a new facility exceeds the avoided risks costs.*

3. *Consider adding redundancy within the distribution system when replacing existing facilities that have reached the end of their economic life or when performing repairs on existing facilities that require retail customer outages.*

4. *To increase redundancy, consider installing temporary or permanent looped systems, cross-over valves, intermediate line valves, and/or additional shut-off valves in the distribution system when the improvement provides positive net present value to the system.*

5. *When evaluating net present value of options over the life of the project, include the capital costs of installing the redundancy improvement and all O&M costs such as those to repair the new facilities or to flush any dead-end mains. Also include the benefits of any avoided risk costs, such as the costs of retail customer outages and temporary loss of fire flow.*

5.2 SERVICE LEVELS

SPU developed service levels to manage its water distribution system assets and describe what retail customers can expect of SPU in terms of water pressure, outages, and problem response. Also, a service level was developed to limit the amount of water lost to leakage. Many of the drinking water quality service levels, as stated in the Chapter 3, also apply to the distribution system. Table 5-1 summarizes the distribution system service level objectives and targets used by SPU to manage its distribution system assets.

Table 5-1. SPU's Service Levels for Managing Distribution System Assets

Service Level Objective	Service Level Target
Provide adequate pressure for drinking water supplies.	• Fewer than 1% of retail customers with less than 30 psi* at the meter during normal operations. • By the end of 2008, no retail customers with less than 20 psi during normal operations.
Limit drinking water supply outages	• Fewer than 4% of retail customers will experience water outages for one or more events totaling more than 4 hours/year.
Respond quickly and effectively to water distribution system problems.	• 80% of distribution system problems (emergency situations such as a pipe break; potential contamination of water supply; hydrant damage) responded to within 1 hour.
Meet water use efficiency goals to ensure wise use and demonstrate good stewardship of limited resource.	• Leakage losses of no more than 10% of total supply, as defined by Washington Department of Health guidelines.

* Pounds per square inch.

Each of these service levels, including the rationale and current performance relative to the targets, are discussed below.

Water pressure is the force of water, expressed in pounds per square inch, available from the water system.

5.2.1 Distribution System Pressure

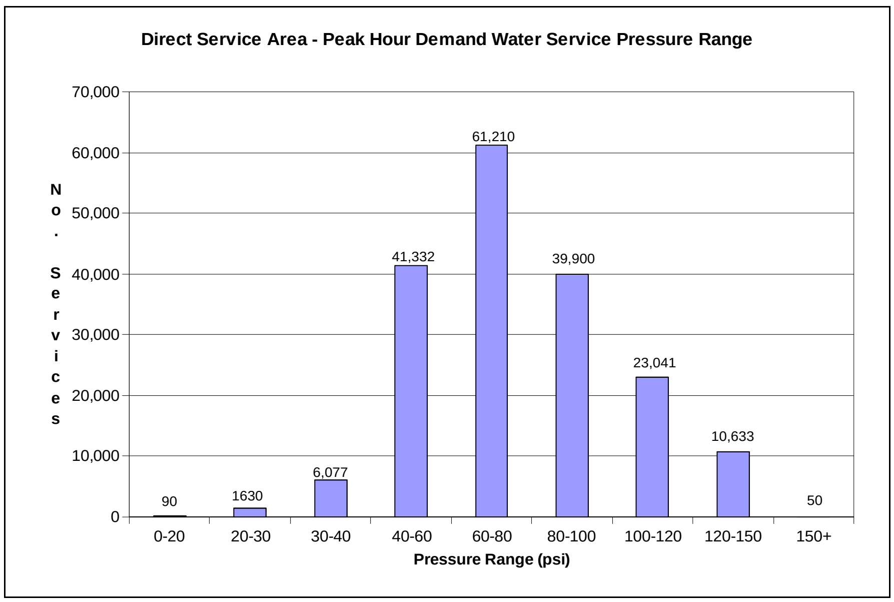
Maintaining adequate distribution system pressure is critical to ensure both customer service and drinking water quality. Adequate water pressure enables customers to have sufficient water flow from their household plumbing fixtures and appliances. In addition, adequate pressure prevents contaminants from entering the distribution system through pipeline leaks and cross connections.

In 2004, SPU developed a service level which meets Washington State Department of Health (WDOH) requirements for pressure and provides a method for an economic analysis of supplying higher pressure levels in new and existing areas of the distribution system. This service level establishes a minimum 20 pounds per square inch (psi) service connection pressure standard for the existing distribution system during normal operations and a minimum 30-psi design standard for new distribution system construction, consistent with the Washington Administrative Code (WAC). Current services with less than 20 psi of pressure will be brought up to at least 20 psi through system improvements.

Services with pressures less than 30 psi will be brought up to a higher pressure when it is economical to do so.

More than 99 percent of SPU water services provide at least 30 psi during normal and peak hour demand periods.

Figure 5-1 shows the overall range and frequency of service pressures within SPU's direct service area based on hydraulic modeling of the entire system. Since more than 99 percent of SPU water services provide at least 30 psi during normal and peak hour demand periods, SPU is already meeting its service level target of less than 1 percent below the 30-psi threshold. Plans to raise pressure at locations with less than 20 psi are described later in this chapter. While the target is to complete these improvements by the end of 2008, issues outside of SPU's control could delay or change these plans.



* Based on hydraulic network modeling using peak day operational data from 1998, with water demands increased by 5%. This is equivalent to a total system consumption of 277 mgd, which is not forecasted to occur until sometime after 2060.

Figure 5-1. Range of Water Pressure within SPU's Distribution System*

5.2.2 Service Outages

Brief service interruptions are inevitable when operating and maintaining a large water distribution system like Seattle's. The interruptions can result from unplanned events, such as a pipeline break or pump failure. More often, service interruptions are planned to accommodate the repair or replacement of an older pipe, a broken valve, a leaking hydrant, or other malfunctioning equipment and, in these cases, notice of the planned interruption is given to customers ahead of time. From the customer's perspective, what matters is that the service outages are infrequent and short in duration.

SPU's service level target for service outages is that in any year, fewer than 4 percent of retail customers will experience water outages for one or more planned or unplanned events totaling more than 4 hours. The 4 percent/4 hour target was modeled after that used by other water providers. It currently serves as a baseline for collecting data on retail service outages. During 2005, only 1.1 percent of retail customers experienced cumulative outages of more than 4 hours from planned and unplanned events.

5.2.3 Response to Distribution System Problems

Although distribution system problems are infrequent, their occurrence requires a timely and effective response to ensure that water service is restored and safe drinking water is delivered. SPU's problem response service level provides that for 80 percent of potentially high priority distribution system problems, SPU will respond within 1 hour of being notified of the problem. High priority problems are those that potentially present an immediate public health or safety concern, and include pipe breaks, hydrant damage, or potential contamination of the water supply.

Using its computerized maintenance management system, SPU tracks high priority problems reported in the retail service area and how long it takes crews to be on site and begin resolving the problems. During 2005, SPU responded to more than 80 percent of high priority problems within 1 hour.

5.2.4 Leaks

Leakage is only one component of non-revenue water.

While some level of leakage is unavoidable, it is important to SPU to keep leakage to a minimum because it represents a waste of valuable resources and may result in water damage to property. WDOH is developing a requirement that would limit system losses from all leaks to 10 percent of the total water produced. SPU intends to meet the WDOH requirements with this service level.

SPU's water system has had a history of low leakage rates. In 2005, SPU's total non-revenue water was 9.3 million gallons per day (mgd), or 7 percent of the total 128 mgd produced. Leakage is only one component of non-revenue water; other components include seepage and evaporation from open reservoirs, water used for flushing and firefighting, as well as meter errors. Current leakage from SPU's distribution and transmission system is estimated at between 3.3 mgd and 4.8 mgd. Approximately 15 percent of the leakage comes from transmission pipelines and water mains, and the remaining 85 percent comes from service connections on SPU's side of the meter.

5.3 EXISTING SYSTEM AND PRACTICES

The water distribution system consists of the facilities that deliver treated water to SPU's retail water customers.

The water distribution system consists of the facilities that deliver treated water to SPU's retail water customers. Distribution system facilities include water mains, storage facilities, pump stations, retail customer meters, and other appurtenances. The water distribution system contains more than 1,600 miles of water mains, most of them 6 to 12 inches in diameter. Seattle's water distribution system also includes two open reservoirs, seven covered reservoirs, 15 pump stations, and ten elevated tanks and standpipes. In addition, the City has more than 180,000 service lines and meters serving individual residential and non-residential properties.

Since the *2001 Water System Plan*, major improvements in the distribution system have included covering Bitter Lake and Lincoln Reservoirs as described in Chapter 3. Burying of Beacon and Myrtle Reservoirs began in 2006, and the Queen Anne Tank and Pump Station Projects are being implemented. Numerous water main improvement projects have also been completed in conjunction with redevelopment and other agency projects, such as Sound Transit transportation projects. SPU has also proactively replaced plastic service lines, due to the high rate of failure for this pipe type, where it was economical to do so. In addition, a new SCADA system has been placed into service.

The following sections provide a description of the major classes of distribution system assets and a brief summary of their condition. The distribution system facilities O&M practices are also described, with attention given to changes in these practices or facilities since the *2001 Water System Plan*.

5.3.1 Existing Infrastructure

A description of the major components of SPU's water distribution system, a summary of their condition, and SPU's replacement/ renewal strategy is summarized below. A detailed inventory of the major asset classes is provided as an appendix.

Water Mains

Seattle owns a network of 1,641 miles of water mains within its retail service area. Since the *2001 Water System Plan*, many water main improvement projects have been completed, with a number completed in conjunction with re-development and other agency projects, such as Sound Transit transportation projects. However, the overall configuration of the distribution system remains unchanged since 2001.

The condition of SPU's water mains varies based on a number of factors including age, material, size, date of installation, and site specific conditions such as soil type and water table depth. The years of installation of distribution water mains is shown in Figure 5-2.

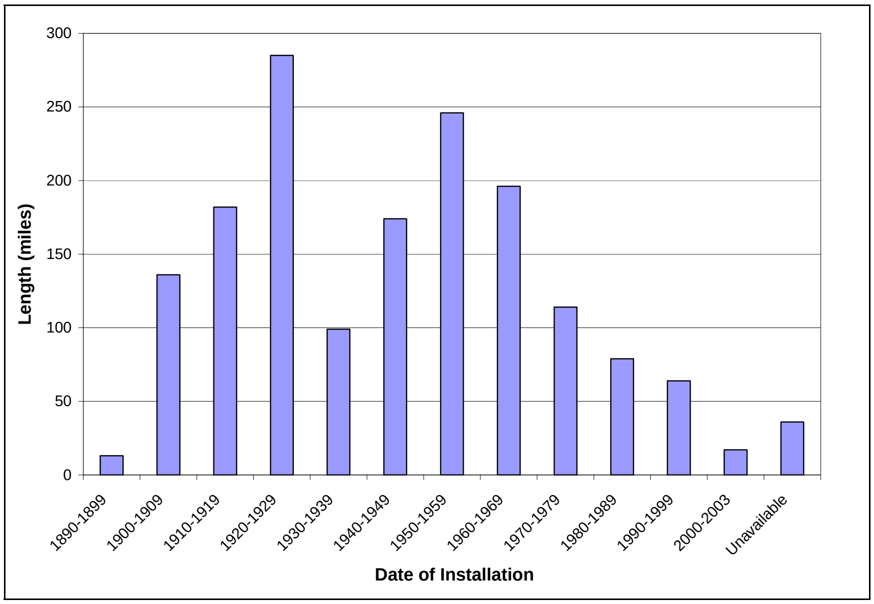


Figure 5-2. Year of Installation of SPU's Distribution System Water Mains

SPU does not have specific condition assessment information for most of the distribution system, since inspections are performed only following pipe breaks. Without specific condition assessment data, the most appropriate measure of condition of the water mains is the leakage rate. Based on data from 1995 to 2005, the leakage rate of water mains is low, averaging approximately 8 reported leaks per 100 miles per year in the distribution system. This is less than half the rate of other major water utilities in the western United States. SPU's total water loss from water mains is estimated to be approximately 0.5 to 0.7 million gallons per day, or between 300 to 430 gallons per day per mile. The International Water Agency (IWA) estimates that water loss from water mains should be approximately 370 gallons per day per mile for a well-run utility.

As a result of SPU's ongoing water main replacement program, SPU's water main break rate dropped from approximately 12 to 8 breaks per 100 miles during the past decade.

Water mains continue to be replaced as part of SPU's ongoing water main replacement program, which replaces leaking pipelines at the most economical time. During the 1990s, SPU proactively replaced a number of galvanized iron water mains that were exhibiting higher break rates than pipes of other materials. As a result of this program, SPU's water main breaks per 100 miles per year dropped from approximately 12 to 8 during the past decade.

Tuberculation is the development of small mounds and growths of corrosion (rust) inside of pipe.

Approximately 700 miles (43 percent) of The City's water mains are composed of unlined, cast iron pipes. As these pipes age, many of them exhibit varying degrees of tuberculation, small mounds and growths of corrosion (rust) inside of pipe. Tuberculation increases the pipe wall roughness inside of the pipe, thereby increasing resistance to water flow which reduces pipe flow capacity, increases pumping costs, and causes water quality problems such as discoloration, low chlorine residuals, and taste and odor problems. SPU is completing a pilot project to clean and apply cement mortar lining to restore these pipes at a fraction of the cost of replacing them. Since cleaning and lining work generally does not require pipeline excavation, there is less disruption to the community than with pipe replacement. If this pilot project is successful (i.e., if it is cost effective, improves water quality, improves flow, etc.), SPU will establish a long-term program to apply this lining to the unlined cast iron pipe in the distribution system.

Distribution System Water Storage Facilities

SPU's distribution system includes eight in-city reservoirs and ten elevated tanks and standpipes to provide regulating and backup storage capacity to its retail customers.

Distribution System Reservoirs. The City of Seattle owns and SPU operates and maintains eight reservoirs in the distribution system. Bitter Lake was retrofitted with a liner and floating cover beginning in 2001, and Lincoln Reservoir was reconstructed as a buried reservoir beginning in 2004. The Beacon and Myrtle reservoir replacement projects began in 2006, when the existing reservoirs were taken out of service. SPU is investigating the possibility of retiring the last two open reservoirs, Volunteer and Roosevelt.

Condition assessment of in-town reservoirs follows the same procedure as described for the water transmission system reservoirs. Based on inspections, the structures are in good condition. Roosevelt's high-density polyethylene liner was replaced in 1990 and, with an estimated life expectancy of 20 years, is not likely to need replacement before the reservoir is decommissioned. Volunteer, View Ridge, and Magnolia Reservoirs are unlined. The leakage rate from Bitter Lake, Roosevelt, and Magnolia Reservoirs is low, measured in 2003-2004 at under 0.6 gallons per minute per million gallons (gpm/MG). The 2003-2004 leakage rates for Volunteer and View Ridge Reservoirs were 3.5 and 2.6 gpm/MG respectively. Leakage from Lincoln Reservoir was tested during construction and found to be minimal and within acceptance criteria.

Distribution System Elevated Tanks and Standpipes. In addition to its in-town reservoirs, the SPU water distribution system includes two elevated tanks and eight standpipes. The elevated tanks and standpipes were constructed between 1907 and 1996. They range in capacity from 0.88 mg to 1.40 mg. This excludes the Queen Anne standpipes, which are both scheduled for demolition in early 2007, and are planned to be replaced with a single 2-mg tank.

Distribution system tanks and standpipes are inspected and maintained in the same manner as transmission system tanks, as described in the Transmission chapter.

Distribution System Pump Stations

SPU operates 15 distribution system pump stations with a total of 32 individual pump units. These pump stations are inspected regularly to ensure that they continue to function properly and equipment is repaired or replaced as needed. The most significant change to SPU's pump station assets will be the addition of a new pump station on Queen Anne Hill. This pump station will feed a new pressure zone that is expected to address low-pressure problems experienced by customers. Another modification to the pump stations is occurring through the SCADA Valve Upgrade Project, in which SPU is installing position indicators for remote control valves in all of its pump stations to help with system operations. Aside from minor reconfigurations and component replacements/upgrades, there have been few changes to existing pump stations since the *2001 Water System Plan*.

Distribution system pump stations are maintained in the same manner as transmission system pump stations, as described in the Transmission chapter.

Distribution System Appurtenances

"Distribution appurtenances" include various parts, features and elements that are incidental, integral, or subordinate to the system, such as valves and hydrants.

The SPU water distribution system includes a number of smaller appurtenances, such as valves, hydrants, service lines, and meters. The paragraphs below summarize SPU's inventory and replacement approach for each class of appurtenance.

Distribution System Valves. SPU's water distribution system includes more than 21,000 valves. More than 16,600 valves control the flow of water through the distribution system, but other valves regulate pressure, bypass other facilities, or allow air to escape the system. Most valves within the distribution system are gate valves. The only significant modification to SPU's valves planned since the *2001 Water System Plan* will be the valve chamber replacement program that will replace existing chamber tops and access maintenance holes with larger diameter tops and new access ladders. This program will provide SPU maintenance staff with safer valve chamber access and meet industry safety standards.

SPU has an ongoing program to replace line valves when they fail beyond repair, when no replacement parts are available, or where the cost of repair exceeds the cost of replacement. The determination of when a valve should be replaced instead of repaired is based on consultation among SPU staff experts.

Distribution System Hydrants. SPU maintains more than 18,350 fire hydrants. There are two classes of fire hydrants: in-service hydrants, which are considered suitable for fire fighting, and out-of-service hydrants. SPU maintains in-service hydrants based on inspections conducted by the fire service agency that serves the area. While out-of-service hydrants are not suitable for use in fire fighting, either because they are not in good repair or because the water supply is not adequate for fire fighting, those hydrants may still be used for water main flushing. SPU paints the out-of-service hydrants white to distinguish them from in-service hydrants. SPU maintains the out-of-service hydrants based on information provided by its field personnel. There have been few changes to fire hydrants since 2001.

SPU's hydrant replacement strategy is to take advantage of opportunity projects to replace obsolete hydrants in areas where excavation costs are low and future costs are likely to be much higher. Other than these opportunity projects, SPU replaces hydrants that are found to be not operable, and replaces obsolete ones. New hydrants may also be installed as part of new development.

Distribution System Service Connections. SPU maintains approximately 180,000 service connections, 80 percent of which are ¾-inch diameter pipes. Almost 70 percent of service connections are copper, and 20 percent are plastic. The remaining 10 percent are galvanized iron, ductile iron, and other materials. The most significant change to SPU's service connections since 2001 is the initiation of a program to proactively replace non-copper service connections with copper connections. This program is intended to reduce the high leakage and failure rate of non-copper service connections and is expected to be complete by 2015.

By proactively replacing non-copper service connections with new copper connections, SPU expects to reduce leakage rates.

The most appropriate assessment of the condition of SPU's service connections is their leakage rate. In 2005, SPU's leakage rate from its service connections was approximately 2.8 leaks per 1,000 service connections. This is lower than the IWA's target leakage rate of 3.75 leaks per 1,000 service connections for a well-run utility. The current volume of leakage from SPU's service connections is estimated between 2.8 to 4.0 million gallons per day (mgd), or between 15 to 22 gallons per day per service connection. IWA's target leakage volume is approximately 15 gallons per day per service connection. SPU's non-copper service connections have leakage rates that are greater than 5 leaks per 1,000 service connections. By proactively replacing these non-copper service connections with copper connections, SPU expects to reduce the service connection leakage rate down to 1.5 leaks per 1,000 service connections, well below the IWA target. For all other copper services, SPU's replacement program is a "run-to-failure" strategy, since the impacts of a failed copper service are typically minor, and the services can be quickly replaced.

Distribution System Meters. Each service line is fitted with water meters used to determine customer charges. Most of the meters (87 percent) are for residential customers, and the remaining 13 percent are for commercial customers. Nearly 92 percent of SPU meters are small (3/4-inch and 1-inch). Since the *2001 Water System Plan*, the most significant change to distribution meters, other than routine meter replacements and repairs, has been the installation of radio frequency modules on difficult-to-read meters in the downtown area. Also, radio frequency modules were installed in 2005 at a group of multi-family residential meters to pilot-test a new technology to collect readings from a single pole-mounted collector.

5.3.2 Distribution System Operation

SPU's water distribution system is primarily served by gravity. For pump stations, valves, and other system components, SPU's SCADA system provides remote control and information feedback to system operators.

SPU operates its water system through its SCADA system. From the control room in the Operations Control Center, SPU water system operators use the SCADA system to remotely control facilities such as pumps and valves. The SCADA system provides real-time data regarding pressure, flow, storage facility water level, and pump/valve status to system operators. Archived SCADA data are also useful for hydraulic network modeling, system planning, and engineering design.

SPU has replaced its obsolete tone-telemetry system with a modern PC-based digital system. The operator interface moved from the 50-foot "big board," where data was displayed on strip charts and light-emitting diodes (LED) readouts, to a personal computer-based system in early 2006. In addition to providing a uniform interface and allowing for automated data collection, this change has removed the limitation for expanding the number of SCADA remote sites. The new SCADA system is among the first post-"9/11" systems, utilizing a balance of physical and cyber security features. A backup control room has been constructed at the SPU North Operations Center to provide redundant system monitoring and control.

SPU is in the process of expanding the number of sites monitored and controlled by SCADA as well as enhancing how the SCADA data is used for system operations and planning. The first phase of SCADA expansion will be completed in 2008-9, and the second phase will start in 2010. An expanded SCADA system will allow SPU to better serve customers through improved service level monitoring and reduced operational risks.

5.3.3 Distribution System Maintenance

Proper maintenance of distribution system components ensures that SPU will be able to deliver reliable water service, reduce the risk of unexpected failures, and provide safe drinking water quality to its customers. SPU has prepared a number of strategic asset

SPU has prepared a number of SAMPs for each major class of distribution system infrastructure components.

management plans (SAMPs) for each major class of distribution system infrastructure components. The SAMPs outline maintenance strategies for each asset. Summaries of those maintenance strategies are provided below.

Water Mains

Water mains located at "dead-ends" or with low flows often accumulate sediment or have the potential for microbial growth. SPU crews flush low-flow or dead-end mains to maintain water quality. SPU has also begun a pilot unidirectional flushing program, as described in the Chapter 3.

Reservoirs and Tanks

Storage facility cleaning is also performed to remove sediment, debris, and/or microbial growth as described in Chapter 3.

Water Pump Stations

Pump stations in the distribution system are maintained in the same manner as described for the transmission system pump stations, as described in Chapter 4.

Water Appurtenances

SPU also performs maintenance activities for its valves, hydrants, service lines, and meters to ensure their continuing operation. A brief description of each follows.

Valves. SPU responds to an average of 100 valve-related problems per year. Most valve problems can be categorized as leaks, casting failures, mechanical inoperability, and valves being buried by new pavement. Deterioration of interior packing, broken and bent stems, and construction projects are usually the causes of valve problems.

SPU is responsible for operating and exercising distribution line valves. Large valves, those 16 inches or larger, were exercised and inspected by valve crews annually until 2003. Due to shifts in priorities, this routine operation work is performed less frequently.

Hydrants. Each fire service agency inspects hydrants located within its service area, generally on an annual basis. Defects are reported to SPU for repair. During a twelve month period in 2002-2003, SPU responded to approximately 2,269 work orders to address fire hydrant defects. During maintenance visits, SPU paints hydrants to prevent exterior corrosion and improve their appearance. The average hydrant painting interval is approximately five years.

Service Connections. SPU spends about $1.2 million annually on reactive maintenance and repair of water service lines extending from the water main to a customer's meter. SPU typically learns of water service failures through customer calls. SPU's service connection maintenance program is almost entirely reactive since it is generally not economical to perform preventative maintenance activities on water service lines. The consequences of failure on water service lines are low, and therefore it is more economical to run them to failure.

Meters. SPU's retail water meters ensure proper billing of its drinking water sales, as well as wastewater disposal costs. Billing system-generated meter problem reports may be generated under a variety of different conditions: broken meter dials; meters that have been inaccessible for reading for three attempts; consumption that is much higher or lower than what is expected for the customer based on historical information; meter registers that are stuck; and meters that show zero consumption. Customer-reported problems often arise from billing questions. When these problems arise, SPU works with each customer to quickly resolve the issues. Malfunctioning customer meters are much more likely to under-register than over-register.

A large meter outside the 97 to 103% accuracy range is either repaired to restore its performance or replaced. SPU does not typically repair small meters since it is generally cheaper to replace than repair them.

SPU maintains its distribution system water meters based on meter size and customer type. SPU has a meter testing and maintenance program for its large meters, which represent less than three percent of all retail meters. SPU's goal is to maintain accuracy of large meters to between 97 and 103 percent as per the guidelines of the American Water Works Association. A large meter with an accuracy falling outside that range is either repaired to restore its performance or replaced.

SPU does not typically perform maintenance activities for small meters since repairing small meters is not cost-effective and it is generally cheaper to replace a small meter than repair it. SPU replaces about 800 small meters each year.

Record Keeping and Reporting

SPU uses its MAXIMO work management system to capture asset failure, repair, and replacement history. Failure history is not completely reliable because many of the failure codes that were originally developed did not adequately describe the nature of the failure. This problem has since been resolved for all new data entered into the system.

SPU uses a geographic information system (GIS) to record and display locations of physical assets and problems. This tool is also utilized to review hydrant spacing and identify hydrants that have deficient spacing.

5.4 NEEDS, GAPS, AND ISSUES

The primary needs, gaps, and issues facing SPU in the coming years are related to low pressures in isolated parts of the distribution system, aging distribution system infrastructure, seismic upgrades, and redevelopment. The following subsections summarize these concerns and SPU's approach to addressing them. SPU's process for resolving customer complaints is also described.

5.4.1 Pressure-Related System Deficiencies

Because of the range of elevations in SPU's water service area, SPU's distribution system is characterized by a wide range of service pressures. To evaluate low pressure areas, SPU uses its detailed hydraulic network models of its entire service area and performs comprehensive modeling of the entire distribution system.

Many of the low pressure situations can be attributed to the fact that portions of SPU's distribution system were designed to the 20-psi minimum service pressure standard in effect when they were originally installed. Other low pressure areas can be attributed to pressure losses due to degradation of pipelines or some combination of low pressure from reservoirs, tanks, or standpipes and pipeline degradation.

Several booster pump station projects have been proposed and built over the years to improve localized low pressure situations. The *2001 Water System Plan* identified the need for a new booster pump station at Phinney Ridge to correct low pressure. However, further analysis found that the area met the 20-psi minimum pressure standard, and it was not economical to construct the pump station to bring pressures above 30 psi.

The following improvements are planned to correct all known areas with service pressures below 20 psi and improve low (less than 30 psi) pressures in these areas where economical:

- Complete the Queen Anne Pump Station and Main Improvement Project currently in design. The booster pump station project for Queen Anne will benefit all domestic service connections and fire services inside the new zone, regardless of service size. The project will boost pressure for a significant number of services with marginal pressure within the defined new pressure zone to between 30 and 40 psi.

- Correct low pressure services that fall below the 20-psi minimum standard on Queen Anne Hill by expanding the Queen Anne 530 zone, creating a new sub-zone, or transferring the two impacted services to higher zones.

- Improve pressures in the Maple Leaf 530 zone north of the Maple Leaf Tank that are currently below 20 psi during peak hour design conditions. Preliminary engineering studies for these improvements are considering options for addressing the low pressure improvements together with the current Maple Leaf Tank seismic upgrade and painting projects.

5.4.2 Aging Infrastructure

Parts of Seattle's water distribution system, in particular many of its pipelines, have been in place for more than a century. Although the existing system is in good condition, as evidenced by its low leakage rates, the system is continuing to age. In line with its asset management business model, SPU has developed a water main replacement program that provides a framework for making short-term pipeline rehabilitation and replacement decisions and projecting long-term pipe replacement and repair needs. The following sections describe the short-term and long-term aspects of the program and its impacts on future leakage rates and customer outages.

SPU's Approach to Water Main Replacement and Renewal

In general, replacement of a pipeline is economically justified when the cost of replacement is lower than the projected cost associated with repairing it.

SPU has developed a distribution system renewal program that provides a high level of service to its customers while minimizing the life-cycle cost to the system. The life-cycle cost of an asset is the cost of owning, operating, maintaining, and disposing of that asset over its life. In general, replacement of a pipeline is economically justified when the cost of replacement is lower than the projected cost associated with repairing it. SPU's approach is based on industry-accepted best practices for infrastructure asset management that are widely used by water utilities in Australia, New Zealand, the United Kingdom, and more recently, by utilities in the US.

SPU uses three tools, Waverider, a Pipe Replacement Model, and an Opportunity Model, to provide repeatable and supportable methods for making decisions about current and future capital and maintenance expenditures. In addition to these models, SPU has pipe rehabilitation programs to address water quality, pressure, and fire flow deficiencies.

Waverider Model. Waverider is a tool that SPU uses to project the long-term ownership costs of particular asset classes, such as pipelines. Replacement costs are projected by assuming that pipes will be replaced when they reach the end of their economic lives. The model considers the current age distribution of each pipe category to determine the length of pipe and cost in each year into the future. As shown in Figure 5-3, Waverider estimates an annual replacement cost of about $2 million for the near term for SPU's water pipes. That annual expenditure for replacement is projected to increase each year as pipelines age until it reaches $38 million in 2100.

The costs for repair of leaking pipes are projected to increase as each pipe category approaches the end of its economic life. Repair cost estimates in the years leading up to end of life are based on failure probability curves for each pipe category. The parameters defining these curves, and the economic life for each category, are adjusted yearly by SPU so that the current number of leaks and replacement cost in the model match the actual numbers. Figure 5-4 shows the current annual repair cost projection from Waverider is $1 million and peaks to about $16 million in 2097.

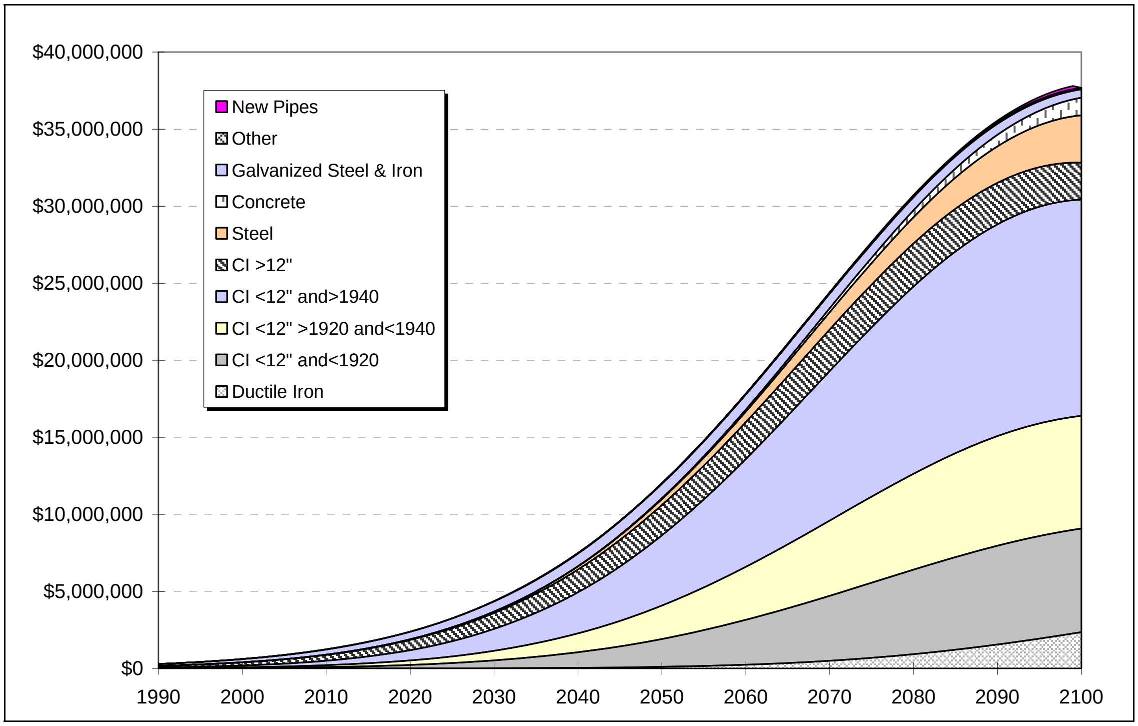


Figure 5-3. Long-Range Pipe Replacement Annual Cost Projection from Waverider for Different Types of Pipe

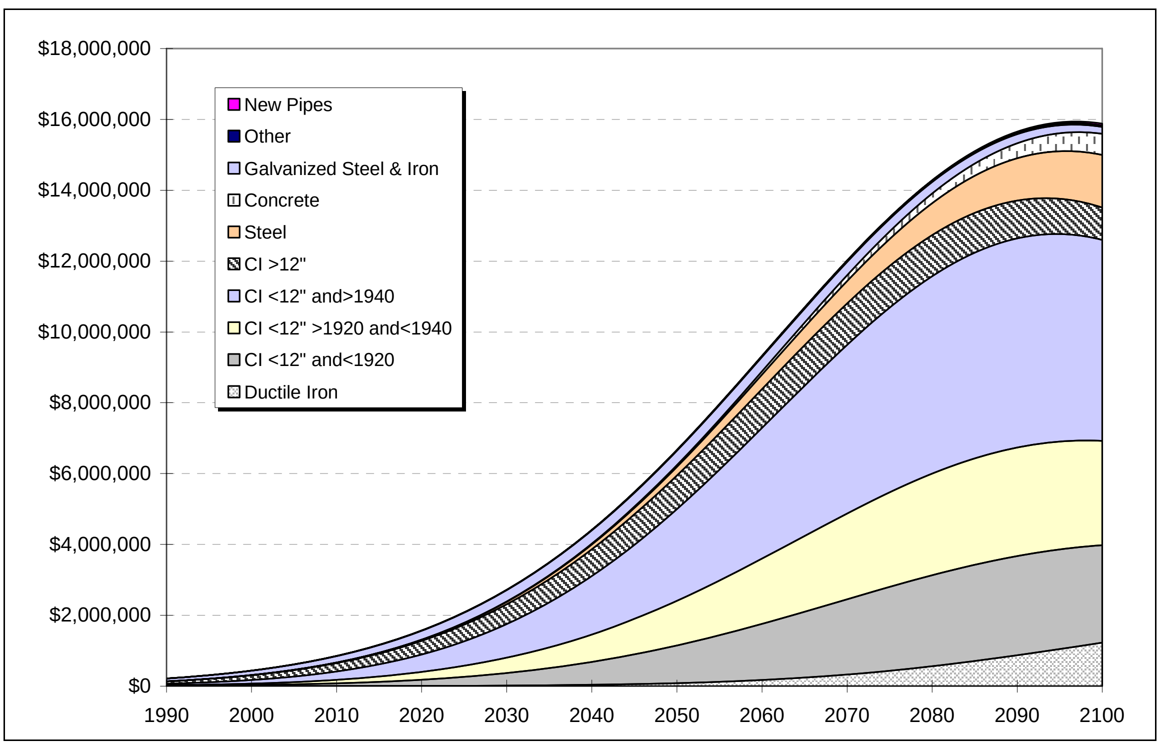


Figure 5-4. Long-Range Pipe Annual Repair Cost Projection from Waverider for Different Types of Pipe

Pipe Replacement Model. Whereas Waverider is a tool for projecting capital and O&M costs far into the future, the pipe replacement model is used to facilitate making decisions to replace specific pipe segments based on the benefit of avoided repair costs. Pipes with a series of recent failures are identified quarterly as pipe replacement candidates. The model compares the annualized cost of installing a new pipe to the marginal cost of repairs for the existing pipe to determine whether pipe replacement or continued repair is more cost-effective. In accordance with SPU's asset management framework, the costs analyzed include social and environmental costs, such as indirect cost for service outages, water loss, and traffic impacts. In recent years, the pipe replacement model has justified spending approximately $1 to 2 million per year on pipeline replacement.

Opportunity Model. In addition to relying on the pipe replacement model, SPU has numerous opportunities to reduce replacement costs by timing replacement with an upcoming capital project, such as a street pavement project. This coupling of projects reduces mobilization costs or street pavement restoration costs. This is advantageous if the cost saved is greater than the expected cost of replacing a pipe too early. SPU's opportunity model provides a tool to make these project timing decisions in a consistent manner.

Other Programs. SPU has other pipe rehabilitation programs to address water quality, seismic, and fire flow issues. SPU began implementing a pilot cleaning and lining program in 2005 for approximately 19,000 linear feet of unlined, cast iron pipe in the Ballard area. This project is expected to provide improved water quality, higher flow capacity, increased pressure, and added pipeline life while minimizing disruption to the community at a third of the cost of pipeline replacement. If the pilot is successful, SPU will re-line more of the 700 miles of unlined, cast iron pipe in the SPU system.

System Leakage

While SPU's Waverider and Pipe Replacement Model are useful in projecting long-term budget needs and deciding whether to repair or replace a particular pipe, costs are not the only concern for SPU. The water utility is also committed to meeting service levels described earlier in this chapter. One service level pertinent to aging pipes is system leakage. SPU's service level for leaks requires limiting total water system leakage to less than 10 percent. SPU has examined its leakage history and projected its system leakage well into the future in an effort to ensure that its replacement strategy meets the level of service.

Current Leakage. SPU's system leakage from pipes was estimated in the *2001 Water System Plan* to be up to 5.7 mgd. This value was based on quantification of SPU's non-revenue water. Recent system investigation has revealed that the 5.7-mgd estimate is probably high. Analysis of leakage using a methodology similar to that developed by the IWA for unavoidable real losses developed a range of estimates of the current leakage. Estimates of SPU's current system leakage losses from distribution and transmission pipelines, including service lines, using the IWA method, range between a low of 3.3 mgd and a high of 4.8 mgd, or between 3 and 4 percent of SPU's 128-mgd production in 2005.

Projected Leakage. To forecast future leakage rates, SPU used future projections of reported water main breaks from Waverider as well as assumptions regarding background leakage and unreported leaks and breaks for water mains and service lines. Table 5-2 summarizes the results of these calculations, showing the estimated leakage now and the projected leakage in 2095, when the system leakage is expected to peak, after which it begins to decline as the rate of pipe replacement increases. The table demonstrates that the projected leakage from all sources is not expected to exceed 10 percent of total system demand, as per SPU's level of service.

Table 5-2. Projected System Leakage

Method	Current Leakage	Projected in 2095	Exceeds 10% limit?
Low Estimate	3.3 mgd	9.1 mgd	No
Middle Estimate	4.1 mgd	12.4 mgd	No
High Estimate	4.8 mgd	15.7 mgd	No

Projected Outages

Water outages, where customers are without potable water for a period of time, can be caused by both planned and unplanned activities. SPU has a water outage service level target that fewer than 4 percent of retail customers will experience water outages for one or more events totaling more than 4 hours per year. Assuming that the number of customer services remains constant at 180,000, achieving SPU's service level target would mean that the number of services experiencing outages of more than 4 hours would be 7,200. While SPU is currently well within the 4 percent target, it is important to determine whether the planned replacement program will allow SPU to meet the service level in the future.

Current Outages. The number of services affected by outages longer than 4 hours per year is approximately 2,061 services, or 1.1 percent of customers based on 2002-2005 data.

Future Outages. SPU projected the future number of outages greater than 4 hours in duration per year from the projected number of water main failures and replacements from Waverider. The number of services affected per outage was then used to calculate the total number of services affected by outages in future years. It was assumed that outages caused by water main leaks and breaks and planned pipe replacements would increase according to the Waverider projections, while outages resulting from all other causes, such as new water main installations, relocations, broken service connections, and repairs/replacements of valves, would stay constant at the current levels.

Figure 5-5 shows the projected annual number of services affected by outages of greater than 4 hours for the next 100 years. The horizontal line represents the target maximum is 4 percent (7,200 customers), assuming the total number of service connections remains constant at about 180,000. The projections reach this line in 2052.

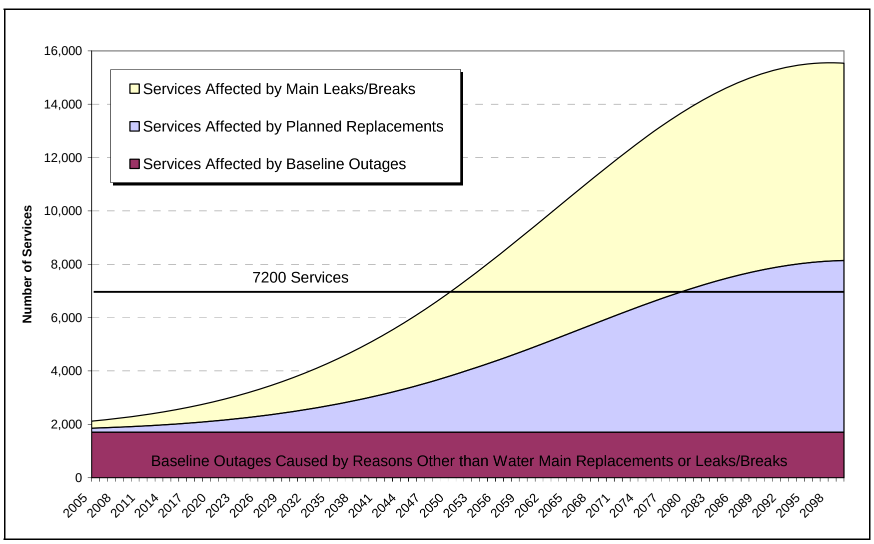


Figure 5-5. Projected Number of Services Affected by Outages Greater than 4 Hours per Year

Because the number of services affected by planned and unplanned outages is projected to be below the service level target for many decades, SPU has time to calibrate the assumptions, gather additional information, and assess needed changes. SPU is examining a variety of possible strategies to avoid exceeding the target, including adding redundant valves or loops, using temporary lines, and throttling valves instead of shutting them completely while repairs are made. In addition, SPU will be gathering data and refining the Waverider Model over the next 10 years to improve the projections and develop strategies for managing retail service outages.

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5.4.3 System Redevelopment

Redevelopment activities can have a substantial impact on the ability of the existing distribution system to provide sufficient water to customers. Redevelopment typically increases the population density of an area and thereby increases the quantity of water that must flow through SPU's distribution system pipes. Often, extension of the distribution system or improvements to existing water mains in the redeveloped area becomes necessary to accommodate higher water demands and fire flows. Detailed hydraulic models are used in conjunction with area demand forecasts and fire flow requirements provided by the fire department to identify potential water main improvements in redevelopment areas.

New developments must meet the current fire code, and new hook-ups must be made to standard water mains. SPU reviews and provides a water availability certificate for each development as part of the City's permitting process. If there is a gap between what the existing system can provide and what the private development needs, the developer will be required to upgrade the existing system to meet requirements.

5.4.4 Backbone Pipeline System Seismic Upgrades

To mitigate the effects of earthquake pipeline damage on the water system functionality, SPU is implementing a program of backbone pipeline system seismic upgrades. As part of the program, the response of the entire water system to an earthquake that might be expected to occur once in 500 years was modeled to identify areas vulnerable to pipeline failures and water outages. The ground motions from such an earthquake would be similar to the 2001 Nisqually earthquake, except that the epicenter would be directly below Seattle instead of below Olympia, and the magnitude would be larger (7.5 vs. 6.8 for the Nisqually earthquake).

The findings of the hydraulic modeling indicate that large numbers of pipeline failures would likely occur in the Duwamish River Valley during such an earthquake, and would lead to immediate loss of water service in this and other seismically vulnerable areas. System damage and pipe breaks would cause most standpipes and elevated tanks south of the ship canal to drain within an hour or two. Beacon Reservoir would completely drain in approximately 8 hours. As the tanks and reservoirs drained, more and more areas, including Downtown, Capitol Hill, Queen Anne, the Rainier Valley, and West Seattle would lose water pressure.

The hydraulic modeling results show that, with the exception of a few areas, those areas north of the Ship Canal are much less likely to lose water service. The amount of expected damage north of the Ship Canal is expected to be low enough that the damaged areas could be isolated before Maple Leaf and Bitter Lake Reservoirs drained.

Replacing all the existing seismically vulnerable pipelines would cost over $3 billion. Replacing only the backbone pipelines considered essential for delivering drinking water and firefighting would cost approximately $1 billion. SPU has considered more cost-effective approaches to mitigating the seismic risks, including line valves to isolate the Duwamish River Valley area, and reservoir valves to maintain water in the in-ground reservoirs for drinking and firefighting. The exact location, operating strategy, hardware, and SCADA requirements for the line and reservoir valves are being evaluated.

The normal pipeline renewal process will involve replacing existing pipes with more seismic resistant pipe.

In addition to isolation strategies, the normal pipeline renewal process will involve replacing existing pipes with more seismic resistant pipe. As pipelines are replaced as part of the normal renewal process, the pipeline system will gradually become more resistant to seismic events.

5.4.5 Customer Complaint Response

SPU has developed procedures for responding to complaints and problems reported by its retail customers. The vast majority of complaints concern water quality problems, in particular muddy or brown water. Few complaints are made about pressure, and these are almost always found to be on-property service line problems.

Figure 5-6 shows the breakdown of water quality complaints in 2005.

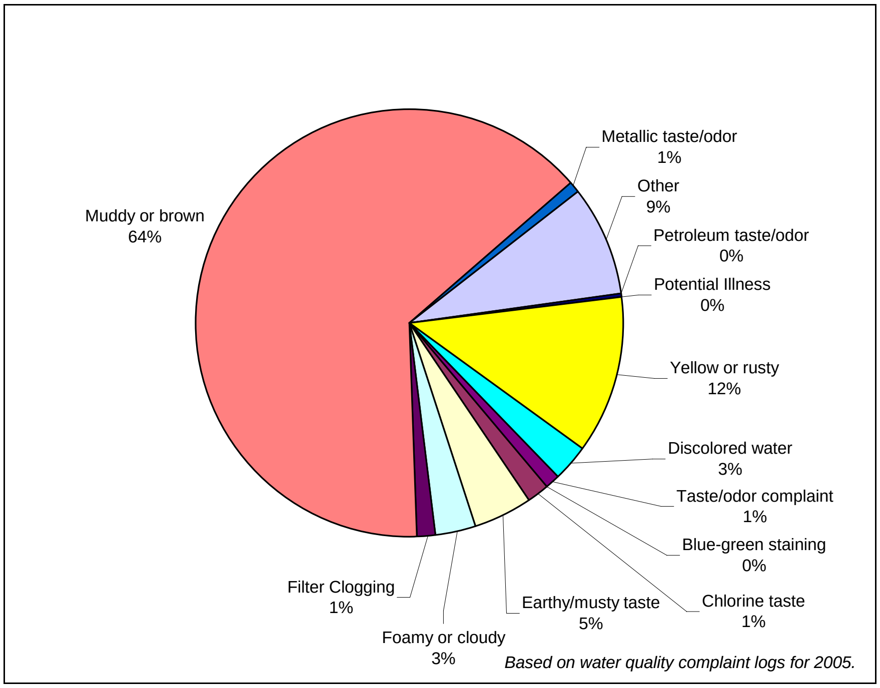

Figure 5-6. Types of Water Quality Complaints in 2005

SPU retail customers with water quality concerns, water service problems, or questions contact the SPU Call Center during normal business hours and SPU's dispatcher after hours and on the weekends. Calls that involve water quality concerns or identify high priority problems–calls that concern public health issues or safety risks–are immediately forwarded to an inspector who will investigate the problem until it is resolved.

SPU is able to better track the customer calls from the service orders created.

The current procedures, which were implemented in 2003, have several advantages over SPU's former complaint response process, which consisted of customers leaving a voice mail message to which SPU would respond sometime later. The new process puts the customer in immediate contact with SPU staff and provides SPU with up-to-date knowledge of from where the complaints are coming, the nature of the complaints or problems, and how many are being received from a given area of Seattle. SPU is also able to better track the customer calls from the service orders that are created and logged into its computer system. Specific information on individual customers is kept with Customer Service records for a period of five years.

The Laboratory Services Division also maintains records of water quality monitoring related to customer complaints. Records kept on file at the Water Quality Lab for a minimum of five years include any bacteriological and chemistry analyses that are performed.

5.5 Implementation/Action Plan

As described in this chapter, the major issues facing the distribution system include areas with low pressure, appropriate investments for aging infrastructure, upgrading water mains in redevelopment areas, potential damage resulting from a major seismic event, and managing the system to meet service level targets. SPU has identified the following actions to address these issues:

- Improve pressure to areas where services have less than 20 psi on Queen Anne Hill, in the lower Queen Anne 326 pressure zone, and in the Maple Leaf 530 pressure zone.
- Renew or replace aging water mains using the policies and procedures described in this chapter.
- Collect SPU-specific failure data to refine the Waverider Model.
- Continue working with developers where water main replacements or upgrades in redevelopment areas are required to meet current fire flow code requirements and water main standards to make sure that the developers cover upgrade costs.
- Replace backbone pipelines essential for delivering drinking water and firefighting to minimize loss of service following an earthquake. Other approaches to mitigating the seismic risks include line valves and reservoir valves.
- Manage retail service provision, problem response and leakage to meet service level targets.

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